

burning. Only a few weeks of dry weather, with the sun well in the zenith, and hence its rays essentially vertical, are sufficient to make the grasses dry enough for ready combustion. In northeastern Minnesota, where the annual precipitation is about the same as that in the llanos, namely, 750 to 1,000 mm., the rainy season occurs during the summer months, with a primary maximum in June and secondary maximum in September. Yet during late October and November forest and prairie fires are not uncommon. It is true that the pine trees invite fire, but the grasses are probably as succulent as those of the llanos and even these burn readily after a short dry season.

The vegetation of the llanos, therefore, throws little light on the amount of rainfall, and the amount of rainfall so far as it is known does not in itself seem to account for the vegetation. For the present, and until observations through a series of years become available, the assumption remains that the rainfall of the dry season is due to the moisture carried inland by the northeast trades, encouraged as it were, to penetrate so considerable a distance, by the trough formed between the Cordillera Oriental and the Guiana highlands, combined with local excessive heating which induces a lower pressure than that existing to the northeastward of the area. The wet season results from a northerly

extension of the doldrums during June, July, and August. These, however, are probably not so effective as farther south, owing to the intensity of local convection, which may be sufficient to carry moisture to elevations of over 15,000 feet where strong westerly winds of the upper air circulation can carry the water vapor away before condensation is accomplished.

No mention is made in the literature, of a local mountain wind from the Cordillera Oriental corresponding to the chinook of North America or the bora of the Adriatic. It seems possible that a local wind resulting from differences in temperature between the crests of mountains and the plains below might develop during the doldrum period, when convection is strong over the plains. An accumulation of cold air on the mountains in sufficient masses could gain large momentum moving down the rather steep slopes and develop into evaporating winds of consequence. This would tend to counteract some of the precipitation which normally should fall in quantity under the doldrum influence. Further exploration of the area might reveal the presence of such winds.

The question, then, of the cause of the apparent dryness of the llanos and the absence of trees in inter-stream areas must remain in the hypothetical stage. The statements here offered are presented as suggestions and possible bases for further inquiry.

#### SOME ILLUSTRATIVE TYPES OF LATIN-AMERICAN RAINFALL.<sup>1</sup>

551.578.1 (8=6)

By BERNARD O. WEITZ.

[Washington, D. C., Nov. 15, 1921.]

#### SYNOPSIS.

The following is a discussion of a few graphs showing the monthly distribution of rainfall at selected stations in Latin America. These have been grouped as follows:

1. Mexico, Central America, and the West Indies.
2. Western coast of South America (3 sections).
3. Northeastern South America and the basin of the Amazon.
4. Eastern South America, Brazil, Argentina, Paraguay, and Uruguay.

#### INTRODUCTION.

The accompanying graphs were prepared to supplement Van Cleef's rainfall maps published in this REVIEW. It is of interest to note the effects of the precipitation controls of Latin America, not only on the annual and seasonal distribution of rainfall, but also the precipitation from month to month.

Twenty-five representative stations<sup>2</sup> were selected, embracing the various types of rainfall found throughout the region. The effects of prevailing winds, shifting wind belts, mountains, and ocean currents is to produce a diversity of rainfall types. When we correlate the geographic coordinates of various localities with the climatic controls mentioned above, the explanation of the different types usually becomes apparent. The characteristic distribution and climatic factors affecting these types are discussed.

*Mexico, Central America, and the West Indies.*—Over this entire area the most important of the precipitation controls is the northeast trade, with its characteristic winter maximum on windward coasts and mountains.

The southern part, however, especially the leeward shores (cf. Panama), is subject to the midsummer convectional rains accompanying the northern position of the heat equator belt of calms (doldrums).

In most of Mexico the annual minimum comes during the winter and early spring, the region being too far south to be affected much by the southern extensions of strong extra-tropical lows. The maximum comes late in summer, the moisture for these convectional rains coming from the Gulf of Mexico. Mexican rainfall may be described as the marginal tropical type, the trade-belt rains being affected<sup>3</sup> by the migration of the equatorial rain belt with the northward and southward movement of the sun. During this time the trades seem to strike the windward coast from a more easterly direction than during the winter, when they blow from the northeast and have a drying influence.

In the West Indies the principal control is the northeast trade. Owing to the east-west trend of the mountains in Cuba, Santo Domingo, and Porto Rico, the northern and eastern coasts are much moister than the southern coasts, and the monthly distribution on the windward side of the mountains is also more equable than on the lee side. The minimum occurs in February, with another secondary minimum in midsummer, when the trades are weakest.

Over the Isthmus of Panama rains are fairly heavy.<sup>4</sup> Here we again find, considering the Canal Zone as a whole, two annual rainfall maxima, one in May and the second in October. The seasonal minimum occurs during the first three months, March usually being the driest month. The rains are, to a large extent, convective,<sup>5</sup> thunderstorms being frequent, especially over the Isth-

<sup>1</sup> The preparation of this paper was begun in connection with a course in "Climates of the World" conducted by Prof. C. F. Brooks, at Clark University Summer School 1921.

<sup>2</sup> In order to get the longest normals conveniently available, the following were referred to:

(a) Hann's *Handbuch der Klimatologie*, Stuttgart, 1908-1911, vols. 2 and 3.  
(b) Voss: *Niederschlagsverhältnisse von Südamerika*, Petermann's *Mitteilungen*, Gotha, 1907.

It is recognized that the averages given are in some cases based on short records, but it is obvious that the essential characteristics of longer records, with respect to seasonal distribution of rainfall, would be the same.

<sup>3</sup> R. DeC. Ward, *Climate*, G. P. Putnam's Sons, 1908-1918, pp. 84-85.

<sup>4</sup> F. D. Willson, *The climatology and hydrology of the Panama Canal*, *Proceedings International Engineering Congress*, San Francisco, Calif., Sept. 20-25, 1915.

<sup>5</sup> H. G. Cornthwaite, Panama rainfall, *MONTHLY WEATHER REVIEW*, May, 1919, 47: 298-302.

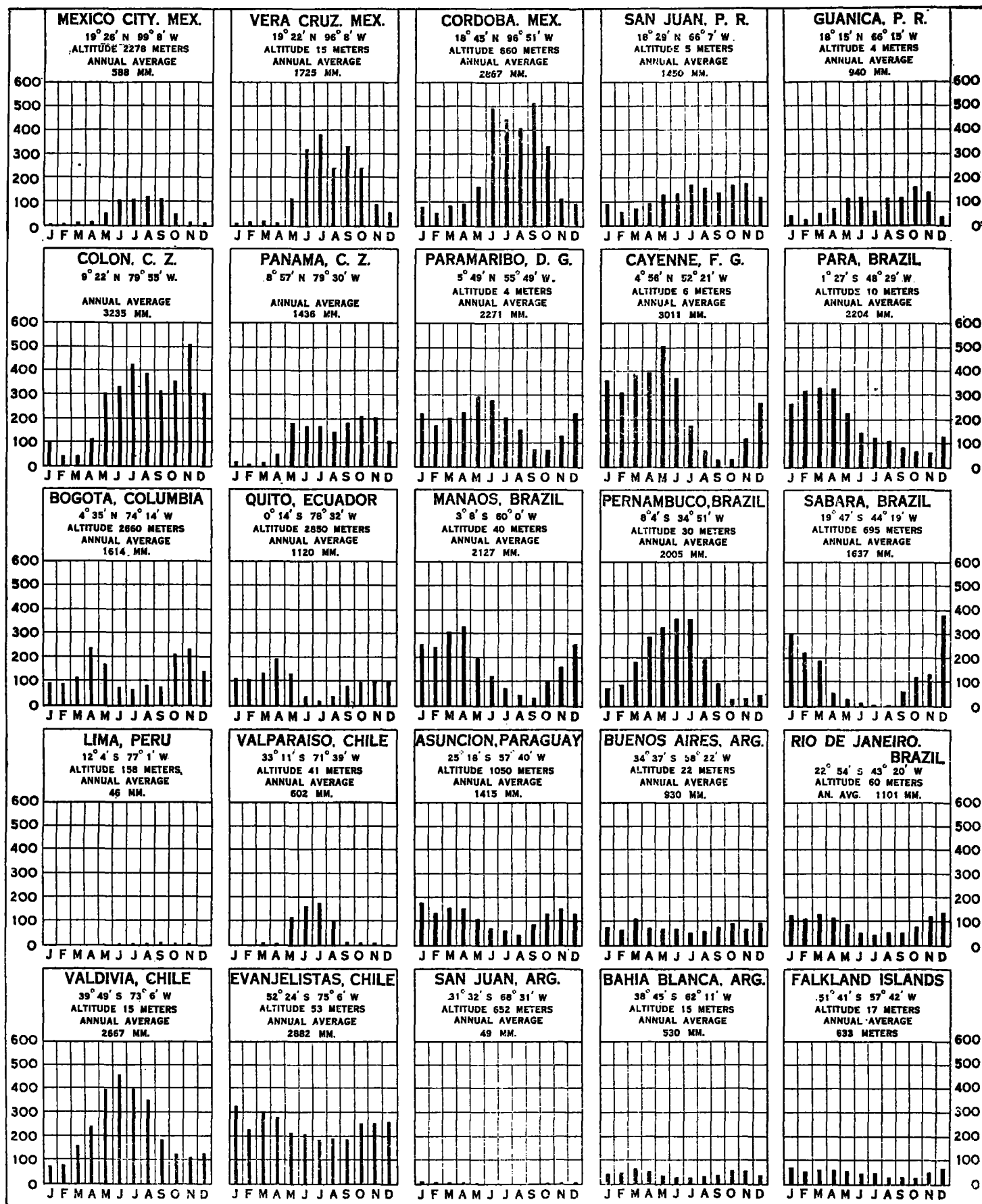


FIG. 1.—Latin American rainfall types.

mus. A study of curves showing hourly distribution of rainfall at several stations shows most of the rain falling in the afternoon, with the maximum at 3 p. m.

*Western coast of South America.*—For the western coast of South America three rainfall types are presented. The first is in the area comprised by the region whose southern boundary is about 4° south latitude, and the northern boundary of which is the Isthmus of Panama. The region has a moderately heavy rainfall with a well-marked double maximum (Bogota). The distribution is controlled by the oscillation of the equatorial rain belt, the maxima occurring when the sun is near the zenith and the minima when the sun is farthest north and south.

The latitudes of the southeast trades along the west coast have the second type. This region extends from about 4° south to 30° south latitude and is essentially rainless. The winds from the east descend the western slopes of the Andes as dry, hot winds, having dropped all of their moisture on the eastern slopes. More prevalent still is a southerly<sup>6</sup> wind blowing parallel to the coast. This wind blowing over the cool Humboldt Current carries but a small amount of moisture, and becomes drier still as it draws nearer the Equator. South of latitude 30° the rainfall is controlled by the prevailing westerlies. Here under the régime of these moisture-laden winds the annual amounts are heavy. The northern part (Valdivia) of this region has a well-marked maximum in June and July (winter) with the maximum of cyclones. The southern part (Evangalista) does not have this maximum, the distribution being fairly uniform throughout the year. The westerlies in these latitudes, popularly designated as the "roaring forties" and the "brave west winds,"<sup>7</sup> bring a procession of frequent and severe storms throughout the entire year.

*Northeastern South America and the basin of the Amazon.*—The rainfall of this region is controlled by the trades and the seasonal shifting of the thermal equator. The monthly distribution of rainfall at Georgetown, Paramaribo, and Cayenne is very similar, although the annual total at Cayenne is larger, possibly, on account of its greater exposure to the northeast winds. The maximum occurs during the spring with the maximum monthly amount in May.

Rainfall is plentiful throughout the entire Amazon Basin. The prevailing winds in this region during the greater part of the year are from the east-northeast. These winds are moist when they enter the region, and the forested Amazon being virtually at times an inland sea, the atmospheric moisture is maintained or increased by evaporation. The seasonal maximum throughout the central part of the basin occurs about a month earlier than in northeastern Brazil and in the Guianas. It is interesting to note that the monthly distribution at Manaus is somewhat analogous to that at Cayenne.

*Eastern South America, Brazil, Argentina, Paraguay, and Uruguay.*—The northern part of this region is under the régime of the southeast trade. On-shore winds from the southeast and an elevated coast line give Pernambuco and stations in this region a heavy rainfall with a primary maximum during the winter when the trades are strong-

est, and a secondary convectional maximum in summer when the doldrums are south.

Southern Brazil (Sabara and Rio de Janeiro), Bolivia, Paraguay, and the interior of Argentina are subject to a summer convectional maximum occurring when the doldrums are farthest south.

As we reach the latitudes of the westerlies along the Argentine littoral we find that the annual rainfall is well distributed throughout the year, March being somewhat more moist than the other months, and a suggestion of an annual minimum occurring during July. Over the estuary of the Plate thunderstorms are fairly frequent during the warmer season, averaging about 7 per month during December and January.

Going westward from the Argentine coast there is a rapid decrease in the annual rainfall, and the Provinces at the foot of the eastern slope of the Andes (San Juan) are almost as arid as that part of the west coast in the latitudes of the southeast trade.

The southern tip of the continent is well watered on both coasts. Two factors account for the moderate heavy precipitation of southeastern Patagonia, namely, the lowering of the Andean cordillera,<sup>8</sup> and the frequent cyclonic storms of these latitudes.

The graphs and discussion presented herewith have not covered the varied complexity of all rainfall types found in Latin America. Only the most essential of the rainfall types have been included and an attempt has been made to show some of the climatic controls governing these types.

#### RAINFALL MAP OF SOUTH AFRICA.

By J. R. SUTTON.

[Excerpts from a paper presented before the Royal Society of South Africa, Oct. 20, 1920. Reprinted from *Nature*, London, Dec. 16, 1920, p. 522.]

A contribution to the study of the rainfall map of South Africa. The monthly and annual rainfalls for 567 stations in South and East Africa are given, and the results shown graphically in 13 maps. The isohyets form a system which moves to and fro across the Equator, following the sun with a lag of a month or more. Corresponding with the general movements of the main isohyetal system are the winter rains of the southwest, which advance inland as the summer rains retreat, and vice versa. The paper concludes with a short bibliography of special studies of South African rainfall.

#### 551.578.1 (048) (728.1) (728.4) RAINFALL IN GUATEMALA AND SALVADOR IN THE YEARS 1908 TO 1920.<sup>1</sup>

By KARL SAPPER.

[Abstracted from *Meteorologische Zeitschrift*, Sept., 1921, pp. 279-281.]

The author has made an attempt to bring together and unify the climatological data of the Republics of Salvador and Guatemala, in which countries the war practically disrupted meteorological work. The following table summarizes the available rainfall records gathered together from various sources.—C. L. M.

<sup>6</sup> R. DeC. Ward, *Climate of South America*, *Bulletin of the American Geographical Society*, 1903, 35:357, pp. 353-360.

<sup>7</sup> R. DeC. Ward, *Climate*, G. P. Putnam's Sons, New York, 1911, p. 112-113.

<sup>8</sup> R. DeC. Ward, *Climate of South America*, *Bulletin of the American Geographical Society*, 1903, 35:359.

<sup>1</sup> *Regenfall in den Republiken Guatemala und El Salvador in den Jahren 1908 bis 1920.*